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The Effect of Outboard Motor Exhaust Wastes on Fish and Their Environment

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ABSTRACT

Bluegill sunfish were placed in liveboxes and sampled at two-week intervals in (1) a lake where much water skiing occurred, (2) in a pond where outboard motors with low-pitched propellors were operated by project personnel, and (3) in a control pond where outboard motors were not operated. The fish were fried in vegetable oil and cracker meal at a temperature of 370°F (188°C) or baked in aluminum foil before being tasted by a taste panel of 12 members. The tainting of fish occurred at a level of about 2.6 gal outboard motor fuel/acre-ft of water or 8 gal fuel/million gal water, and a daily fuel-use rate of 0.17 gal/million gal water (0.055 gal/acre-ft). Threshold odor, carbon chloroform extractables, and chlorine demand showed significant increases in the motor lake and motor pond through the season of outboard motor operation. All water samples from the motor lake and motor pond contained less than 10 µg/1 of lead determined by polarograph.

Laboratory tests conducted in 1960 at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, by English et al. (1963a) showed that bluegill sunfish could be tainted by outboard motor exhaust wastes. Ninety % of persons in a taste panel noted objectionable flavor at a cumulative fuel consumption of 8.6 gallons per acre-foot of water. Half of the panel members noted objectionable taste at 1.1 gallons of fuel per acre-foot.

These laboratory experiments did not show toxicity to fish until the fuel consumption reached 170 gal/acre-ft when half of the fish were killed in 96 hr at a dilution of about 1 in 5. The 96-hour TL_m was, therefore, 19%. When an application factor of 10 was applied for the estimation of the "safe" level, this was projected to 17 gal fuel/acre-ft of water.

Complaints of off-flavoring in fish reached us from a relatively small Ohio lake which was surrounded by cottages and where there was intensive use of outboard motors. These complaints as well as the results of the studies by English et al. reported briefly above, emphasized the need for field studies

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to determine whether fish are tainted or killed by outboard motor exhaust wastes under natural conditions.

The studies were carried out in 1961, as reported by Surber et al. (1962) and by English et al. (1963). The 1962 report dealt mainly with the effects of outboard motor exhaust wastes in the tainting of fish, while the 1963 report included primarily the results of studies of the effects on water quality parameters. Water samples were collected from each of the three water bodies involved in the study for determinations of hydrocarbons, threshold odor, chlorine demand, chemical oxygen demand, and lead. The project was carried out cooperatively by the Chemistry and Physics Section and the Aquatic Biology Section of the Basic and Applied Science Branch, Division of Water Supply and Pollution Control of the Robert A. Taft Sanitary Engineering Center.

Experimental Areas

The field experiments were carried out in three impoundments:

(1) Oeder Lake near Morrow, Ohio, area 6.89 acres, average depth 11 ft, volume 74.8 acre-ft with 40% of the total volume of water contained in the upper 4.5 ft (hereafter called the motor lake). (2) A half acre "sky" pond in the same watershed as the motor lake but receiving no drainage from it. This was the control pond, average depth 6 ft, volume 3 acre-ft. (3) Eggarding Pond (hereafter called the motor pond) had an area of 0.96 acre; average depth of 5.4 ft and volume of 5.2 acre-ft. All were filled by surface drainage from adjacent grassland areas. The average water temperature was 25°C. during the study.

Experimental Methods

Thirty adult bluegills (6-8 inches in length) per live-box were placed in each of the ponds in floating liveboxes 2x2x2 ft, with trap doors 10x10 in., hinged to the wooden top. Two-/or four-mesh galvanized hardware cloth covered the sides and bottom of each box. The fish were fed white bread every other day.

Two liveboxes were placed in the control pond where there was no boating.

In the motor lake, 2 liveboxes were placed at 3 points on the lake at the surface, but outboard motor operators passed as close as possible to them with the result that 50% of the fish were killed within 1 week. We then anchored the boxes out of sight at least 4 feet below the surface where losses were small thereafter.

In the motor pond (Eggerding Pond), the live boxes were held at the surface as in the control pond. The fish were not exposed to excessive wave action as by motor boats in Oeder Lake because the outboard motors used in the motor pond were provided with special low-pitched propellors that permitted up to 4200 rpm and normal fuel consumption without rapid forward propulsion of the boat and violent wave action. In this pond, project personnel operated 4 different kinds of outboard motors: a 10 hp 1960 model; an 18 hp 1960 model; a 10 hp 1959 model, and a 5.4 hp model built between 1939-1949.

The motor lake (Oeder Lake) was privately owned, and outboard motors were operated primarily for water skiing on weekends and holidays. A fairly accurate record was kept at the lake by outboard motor operators who recorded the date, amount of fuel consumed, quantity of oil per gallon of gasoline used, whether gasoline was leaded or unleaded, motor horsepower, and time of operation. Regular grade leaded motor gasoline was used. One half pint to one-fifth pint of oil was added to each gallon.

In the motor pond (Eggerding Pond), 6 popular brands of regular grade leaded motor gasoline and outboard motor lubricating oil were used as fuel. One-half pint of oil was added to each gallon of gasoline in a ratio of 17:1, fuel to oil. Accurate records of all fuel used and time of operation of motors were kept at the motor pond by project personnel.

Fish Tainting Studies

Fish were removed from the liveboxes at intervals of 2 weeks, scaled, and the head and entrails removed. The fish were fried with vegetable oil and cracker meal in an

electric frying pan at 370°F (188°C) or baked in fresh aluminum foil at 350°F (177°C) for 20 minutes. When cooked, each fish was divided in fourths, each of which was wrapped in foil, coded, and kept warm for the taste panel of 12 members. All panel members drank cold milk after tasting each portion. They were supplied with cards upon which they recorded the sample number, date, and checked one of the following: No objectionable taste; slightly objectionable taste; strongly objectionable taste. "Taste" refers to the more inclusive term "flavor." In true taste only sweet, sour, bitter, and salt are detected. "Flavor" embraces, as well, the effect of a substance on the senses of smell and touch. In baked fish samples, tainting was more pronounced than in fried fish.

Briefly, the results of the fish tainting studies were as follows:

Two fuel-use rates were used. The rate of fuel use in the motor lake (Oeder Lake) was not under control, but the weekly average fuel consumption was rather steady over the season (Fig. 1). The average fuel-use rate is equal to the slope of the lines of cumulative fuel consumption. The collection of data on fuel use was begun May 24 in the motor lake and July 14, 1961 in the motor pond. The test period extended from June 1 to September 20, 1961 in the motor lake and the control pond, and from June 29 to September 29, 1961 in the motor pond.

The tainting of fish occurred at a level of about 2.6 gal fuel/acre-ft of water, or 8 gal fuel/million gal water, and a daily fuel use rate of 0.17 gal/million gal water (0.055 gal/acre-ft).

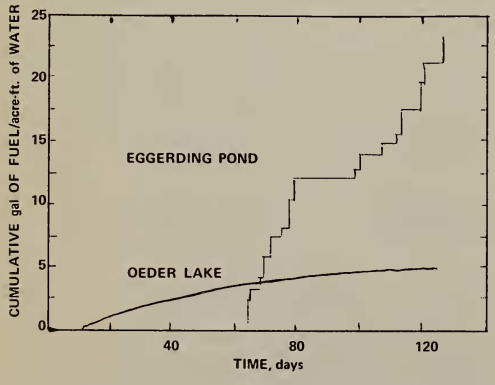

Fig. 1. – Rate of fuel consumption per acre-foot of water.

In the motor lake significant tainting of fish occurred, but the length of time required could not be definitely stated. On the other hand, in the motor pond 66% of the fish portions fried in vegetable oil and 83% of those baked in aluminum foil showed tainting in 35 days. The daily fuel use rate in the motor pond was 1.7 gal/million gal water (0.55 gal/acre-ft).

Results of Water Analyses

The publication of English et al. (1963a) describes in detail the methods used by the Chemistry and Physics Section in the study of threshold odor levels, hydrocarbons, chlorine demand, chemical oxygen demand, and lead.

In summarizing the water analysis data, the threshold odor, carbon chloroform extractables, and chlorine demand showed significant increases in the motor lake and motor pond through the season of outboard motor operation.

Results of Studies

Odor: – In the control pond, the determinations of odor levels in untreated samples did not show a consistent trend, and the results of samples were combined to give an average baseline threshold odor number of 4. In the motor lake, threshold odors of the raw water increased steadily from June 20 to about August 20 to a maximum level of about 16, then decreased as fuel use decreased. In the motor pond, threshold odors also increased as daily fuel consumption increased, reaching a maximum about August 20 of about 23. Again, threshold odor number decreased when fuel use was decreased or halted. Most of the odor panel members described the odor as "musty" and "earthy," but some described the odor as "oily".

Carbon chloroform extracts (CCE): – The organic material in the motor lake, motor pond, and control pond was recovered by activated carbon absorption from 100-gal samples collected below the water surface. The chloroform extracts were

separated into aliphatic, aromatic, and oxygenated hydrocarbons by chromatography on silica gel. The quantity of combined aliphatic and aromatic fractions remained relatively constant throughout the study, even though the CCE increased as hydrocarbon fuel constituents were discharged into the water and decreased when outboard motor operation was halted. There was no definite trend in the CCE extracts from the control pond; the average was 0.39 mg/1. The combined aliphatic plus aromatic fractions averaged 5, 4, and 8% of the total CCE for the motor lake, motor pond, and control respectively.

The lake bottom mud averaged 1.9 mg total extract/g of dry solids and 0.34 mg aliphatic material/g of dry solids; the control pond averaged 1.8 mg total and 0.09 mg aliphatic. The total mud extract from the motor pond increased from 6.6 to 13.3 mg/g of dry solids and the aliphatic from 0.24 to 0.41 mg/g of dry solids over the summer.

Chemical oxygen demand (COD): – There were no significant trends in the chemical oxygen demand data. The average COD values for the motor lake, motor pond, and control pond were 13, 32, and 31, respectively.

Chlorine demand: – The chlorine demand of the motor pond water increased during intense motor operation, decreased when motor operation was halted, and increased again when motor operation was resumed.

Lead: – All water samples from the motor lake and motor pond contained less than 10 µg/1 of lead determined by polarograph after a dithiozone extraction procedure.

Determination of lead in the bottom muds of the motor lake and motor pond showed no lead in the motor lake, but 16 µg/g of dried mud in the motor pond before any outboard motors were operated. The extraneous source of lead remained unknown.

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